Residue Management Tactics for Corn Following Spring Wheat

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Producers are interested in tactics for managing crop residues when growing corn after spring wheat. We compared five systems of managing spring wheat residues: conventional tillage, no-till, strip-till, cover crop (hairy vetch) with no-till, and cover crop with strip-till following spring wheat. Conventional tillage consisted of chisel plowing and disking, whereas strip-till consisted of tilling a 15-cm band centered on corn rows, which were spaced 76 cm apart. Plots were split into weed-free and weed-infested subplots. Grain yield in weed-free conditions did not differ among treatments. However, weed-free yield was nearly 40% greater than weed-infested corn in conventional tillage. In contrast, weeds reduced yield only 15% with strip-till. Weed density and biomass was twofold greater with conventional tillage compared with the no-till and strip-till treatments. Weed seedlings also emerged earlier with conventional tillage. Increased weed tolerance with strip-till may be related to fertilizer placement. Corn growth and tolerance to weeds in no-till systems may be improved if a starter fertilizer is placed in the seed furrow.

Nomenclature: Corn, *Zea mays* L.; hairy vetch, *Vicia villosa* Roth; spring wheat, *Triticum aestivum* L.

Key words: Cover crop, fertilizer placement, interference, no-till, strip-till, weed community.

Producers in the western Corn Belt are considering adding other crops to the corn–soybean [*Glycine max* (L.) Merr] rotation. One reason is to improve pest management because crop rotation helps manage numerous pests (Anderson et al. 2006). Producers are also interested in no-till systems again. Initial experiences with no-till and the corn–soybean rotation often led to low crop yields; yet, adding small grains to the rotation of corn and soybean can eliminate that yield loss, and in some situations, may improve corn and soybean yield (Dick and van Doren 1985; Lund et al. 1993).

One crop being considered in this region is spring wheat. However, producers are concerned that crop residues on the soil surface after harvest may affect productivity of subsequent crops, such as corn. Crop residues on the soil surface can lead to cool soil temperatures in the spring, which suppresses corn seedling emergence and growth and may reduce grain yield (Carter and Barnett 1987).

To address this yield loss, scientists have explored various management tactics related to crop residues, especially with continuous corn. Removing crop residues from a 16-cm band centered on the seed row eliminated yield loss with corn in Iowa (Kaspar et al. 1990). Fortin (1993) found that residue-free bands led to soil temperatures similar to conventional tillage. Consequently, seedling growth improved in the residue-free band, and grain yield did not differ between conventional-till and residue-free bands. Residue-free bands can be established with row cleaners attached to the planter (Janovicek et al. 1997) or by tilling a narrow strip (Pierce et al. 1992).

Another management tactic for high crop-residue conditions is to improve seedling growth with fertilizer management. Vetsch and Randall (2002) found that continuous corn yields in no-till systems were increased by placing a starter fertilizer 5 cm to the side of the crop row. with the remainder of N fertilizer placed below the crop residue layer compared

with broadcast applications of fertilizer. An option with the strip-till system is placing fertilizer in the tilled band below the seed row. In Michigan, corn grown in fields that had been strip-tilled in the fall with fertilizer placed 15 to 20 cm below the soil surface produced yields similar to conventional tillage system in winter wheat stubble (Pierce et al. 1992). Strip-tilling is usually implemented in the fall because of favorable soil conditions and time management.

Producers can gain an additional benefit by including wheat in the corn–soybean rotation; wheat residues lying on the soil surface can suppress weed seedling establishment. Crutchfield et al. (1986) reported that weed density was reduced with 3,000 kg/ha or more of wheat residues compared with bare soil, whereas Wicks et al. (1994) found that weed density decreased 12 to 15% for each 1,000 kg/ha of wheat residues above 3,000 kg/ha. We wondered, however, whether weed density would increase in corn with strip-till systems because the tillage operation not only removes crop residues from the soil surface but also buries weed seeds in soil, which may stimulate weed germination. In northeastern Colorado, tilling once with a sweep plow, a noninversion implement, in wheat stubble increased weed seedling emergence 52% in corn compared with no-till (Anderson 1999). Thus, strip-till systems may reduce suppression of weed establishment by wheat residues.

Another tactic being explored in this region to aid crop production is cover crops (Williams et al. 1998). Producers may be able to accentuate the impact of wheat residues on weed density by planting a cover crop to increase residue levels because suppression of weed seedling emergence is related to the quantity of residue (Teasdale 1996). Also, the additional residue from the cover crop may compensate somewhat for the possible effect of strip-tilling in stimulating weed seed germination. In addition to weed suppression, cover crops may improve corn growth by its favorable impact on N cycling and soil tilth (Hartvig and Ammon 2002).

To answer these questions, we conducted this experiment to compare various management tactics in spring wheat stubble for impact on crop yield and weed interference with

corn. The broader goals with our research program are to increase crop diversity with the corn–soybean rotation and to encourage use of no-till systems yet reduce the need for herbicides for weed management.

Materials and Methods

Site Characteristics. The study was established in the fall of 2000 on a Barnes clay loam (Calcic Hapludoll) near Brookings, SD. The soil contained approximately 3% organic matter, and soil pH ranged from 6.8 to 7.2. Average annual precipitation (84-yr record) is 537 mm, with May and June receiving the greatest rainfall. The study sites were established in spring wheat stubble. Previous to spring wheat, the cropping history of the sites was corn–soybean, with spring wheat established after soybean. Tillage management was chisel plowing and disking.

Residue Management Treatments and Study Design. In 2000 and 2001, a series of residue management treatments was established in spring wheat stubble. Wheat residues on the soil surface ranged from 4,000 to 5,000 kg/ha after spring wheat harvest. Conventional tillage (CT) consisted of chisel plowing in August, followed by disking the following spring to prepare a seedbed. No-till (NT) consisted of two to three applications of glyphosate at 0.7 kg ae/ha to control weeds during the interval between wheat harvest and corn planting. For the cover crop (CC) treatment, hairy vetch was planted at 30 kg/ha with a double disk drill in early August, immediately after harvest into NT wheat stubble. Biomass of hairy vetch when corn was planted the following year ranged from 1,000 to 1,500 kg/ha; biomass samples were collected from two randomly placed 0.5-m[2] quadrats in each plot.

Two strip-till (ST) treatments were established in late October, one in wheat residue (ST) and the second in wheat residue planted to hairy vetch (ST + CC). The ST implement consisted of residue managers[1] that cleared crop residue from a 15-cm band, a tillage shank that penetrated 15 to 20 cm, and two disks that leveled the tilled soil surface. Tilled strips were spaced 76 cm apart from center to center.

The experimental design was a randomized split plot with four replications, with the study repeated at a different site in the second year. Whole-plot size was 6 m by 20 m. Each plot was randomly split into weed-free and weed-infested subplots (6 m by 10 m). Weeds present at planting for both subplots were controlled with glyphosate applied at 0.7 kg/ha. The CC treatments were also terminated at corn planting by adding 2,4-D at 0.4 kg ae/ha to the glyphosate treatment. Weeds establishing in the weed-free subplot after planting were controlled with a POST application of glufosinate at 0.5 kg/ha 4 wk after corn emergence (WAE); later emerging weeds were removed by hand.

Corn, 'NK 3030 LL',[2] was planted on May 23, 2001, and May 13, 2002, at 76,200 seeds/ha. The planter unit had double-disk openers with minimal soil disturbance. Row spacing was 76 cm for all treatments; with the ST treatments, corn was planted in the center of the tilled strip. Fertility levels were based on a yield goal of 8,500 kg of grain/ha. All treatments received 120 kg N, 30 kg P, and 50 kg K/ha, but application technique and placement differed. With the ST treatments, all of the fertilizer, as a liquid formulation, was placed 15 to 20 cm in the soil with the tillage shank in October of the previous year. With the CT, NT, and CC treatments, 10 kg N + 30 kg P + 50 kg K/ha, as a dry formulation, was applied in a band 5 cm to the side of the seed row and 5 cm deep with a single coulter disk attached to the planter. The remainder of N fertilizer (110 kg N/ha) for these three treatments was applied broadcast as ammonium nitrate when corn had six leaves fully exposed.

Weed and Crop Data Collection. Seedling emergence of the weed community was recorded in each year of the study in two 0.5-m[2] quadrats permanently marked in each weed-infested subplot. Each quadrat was randomly placed in the subplot but was positioned to center over a corn row. Counts began 1 wk after corn planting and continued weekly for 7 wk; after counting, weeds were removed by hand. Weed community species, density, and aboveground biomass were also recorded in two randomly located 0.5-m[2] quadrats 8 WAE of corn. Similar to the emergence quadrats, the site for each biomass quadrat was randomly located in the subplot, but at each location, the quadrat was positioned to center over a corn row. The weed biomass samples, which were collected in paper bags and weighed within 30 min of sampling, are expressed as fresh weight.

Plant density of corn was recorded in 3-m sections of two corn rows in each plot 4 WAE, whereas corn height was measured on six random plants in each plot 4 and 8 WAE. Date of tasseling was determined by evaluating six plants per plot on a daily basis; tasseling was defined as the point at which four of the six plants had tassels fully emerged from the last corn leaf. and ear silks were visible; the date of tasseling was expressed as days after July 1. Plant stand, plant height, and date of tasseling were assessed only in weed-free subplots. Grain yield for both weed-free and weed-infested subplots was determined by harvesting 8 m of four rows in each subplot with a small-plot combine. Grain moisture was recorded, and sample weights were converted to 15.5% moisture level.

Statistical Analysis. Data were analyzed by ANOVA.[3] Initial analysis with corn data indicated there was no interaction between treatments and years; therefore, data were averaged across years. An interaction between treatments and weed infestation levels for corn yield occurred, so treatment data were expressed separately for yields in weed-free and weed-infested subplots. Differences among treatment means were determined with Fisher's Protected LSD at the 0.05 level of probability.

Analysis of weed density, biomass, and seedling emergence also showed that data trends did not differ across years. The weekly seedling emergence data were compared among treatments at each recording date. Weekly weed seedling emergence in CT and NT was expressed as the percentage emergence for a given week by dividing the number the number of weeds emerging each week by the cumulative number of seedlings recorded during the 7-wk interval. An emergence curve for each treatment was developed by cubic spline interpolation.[4]
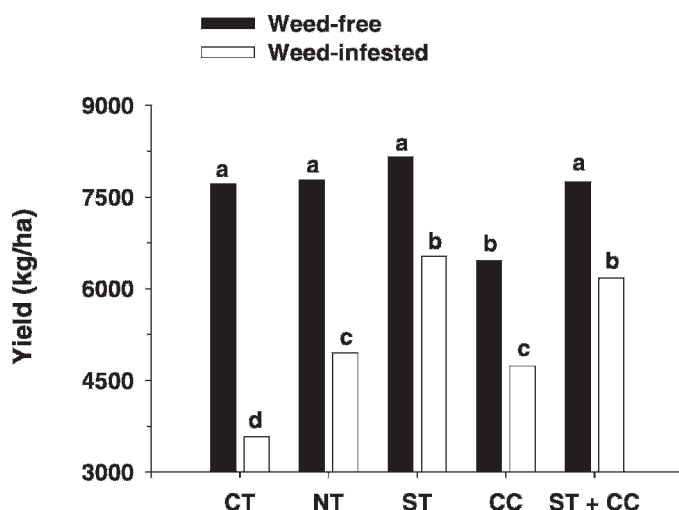
Figure 1. Corn grain yield as affected by residue management treatment. Data are averaged across 2 yr; bars with identical letters are not significantly different as determined by Fischer's Protected LSD (0.05). Abbreviations: CT, conventional tillage; NT, no-till; ST, strip-till; CC, cover crop with no-till; ST + CC, strip-till with cover crop. Hairy vetch was the cover crop.

Results and Discussion

Impact of Residue Management on Corn Yield. *Weed-Free Conditions.* Grain yield did not differ among CT, NT, and the ST treatments (Figure 1). However, yield was reduced approximately 17% with the CC treatment compared with the other treatments. Yield loss in the CC treatment without ST was attributed to poor stand establishment; corn density was approximately 20% less in the CC treatment compared with the other treatments (Table 1). Corn density was not affected by hairy vetch, however, when plots were strip-tilled. The strip-tillage eliminated hairy vetch plants in the tilled zone, which may have improved corn seedling establishment compared with the solid-seeded hairy vetch stand in the CC treatment.

Hairy vetch also delayed corn growth, especially with the CC treatment; plant height at 4 WAE was 35% lower in the CC treatment than in the CT treatment (Table 1). Plant height was also reduced 4 WAE when CC was combined with ST. Although height of corn plants in both CC treatments

was reduced at 4 WAE, the time of tasseling did not differ among any treatment.

Rainfall varied during the early growing season between the 2 yr. In 2001, precipitation in April and May was 33% higher than normal, whereas precipitation during these months was 11% less than normal in 2002. Our interest in this factor is related to results by Vyn and Hooker (2002), who found that corn yield can be reduced by spring wheat residue releasing phenolic compounds that injure corn seedlings. This negative impact on corn growth was most prominent in growing seasons with cool and wet conditions during the corn seedling stage. In our study, the wet soil conditions in 2001 would be most conducive for residue suppression of corn growth, yet corn yield did not differ among various management treatments across years.

Weed-Infested Conditions. Yield loss due to weed interference as compared with weed-free conditions was almost 40% with CT, whereas yields were reduced 25% by weeds within the NT and CC treatments (Figure 1). Corn was more tolerant to weed interference with the ST treatments because weeds reduced yields less than 15%, contrasting with the 25% yield loss in NT with a similar weed infestation level (Table 1). The greater yield loss due to weeds with NT may be related to fertilizer application. With NT, N fertilizer was broadcast on the soil surface; weed growth likely consumed N and reduced its availability for corn. In contrast, N fertilizer was applied below the corn row with ST, which favored corn access the N fertilizer compared with the broadcast application of N with NT. This possible difference is N availability may have increased corn tolerance to weed interference in ST. A study in northeastern Colorado showed that banding N fertilizer by the seed row improved corn yields 15 to 30% compared with broadcast N in weed-infested conditions (Anderson 2000).

The prominent weeds in the study were green foxtail [*Setaria viridis* (L.) Beauv.] and yellow foxtail [*Setaria glauca* (L.) Beauv.], comprising more than 80% of the weed community (data not shown). Other weeds observed included common lambsquarters (*Chenopodium album* L.), common sunflower (*Helianthus annuus* L.), and buffalobur (*Solanum rostratum* Dun.). Weed density was highest with CT, being almost twofold higher, compared with other treatments (Table 1). Strip-till did not increase number of weed seedlings establishing in corn compared with NT, whereas the CC

Table 1. Agronomic data for corn production as affected by wheat residue management and weed community density and biomass (fresh weight). Data are averaged across 2 yr. Means within a column followed by an identical letter are not significantly different as determined by Fischer's Protected LSD (0.05).

		Corn			Weed Community[a] (8 WAE)[b]	
		Plant height				
Residue treatments	Population	4 WAE	8 WAE	Tasseling	Density	Biomass
	plants/ha	----------------------cm----------------------		d after July 1	plants/m^2	gm/m^2
Conventional till	71,680 a	58 a	163 a	25 a	63 a	2,320 a
No till	72,250 a	55 a	160 a	26 a	29 b	900 c
Strip till	72,720 a	58 a	161 a	25 a	32 b	890 c
Cover crop (CC)	57,650 b	38 b	144 b	24 a	35 b	1,390 b
Strip till + CC	70,420 a	41 b	157 a	24 a	28 b	710 c

[a] Weed community was composed mainly of green and yellow foxtail, common lambsquarters, common sunflower, and buffalobur.

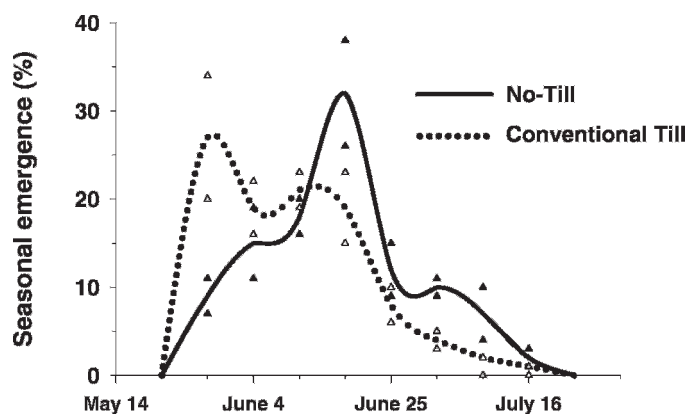[b] Abbreviation: WAE, weeks after emergence; CC, cover crop (hairy vetch).

Figure 2. Seasonal emergence pattern of the weed community in conventional tillage and no-till treatments. Data symbols represent weekly means by years, averaged across replications; solid triangles represent no-till means, whereas open triangles represent conventional-till. Emergence within weeks differed between the two treatments on May 28 and June 18 as determined by Fischer's Protected LSD (0.05).

treatment did not suppress weed emergence compared with NT. The lack of response with CC may reflect the low production of hairy vetch biomass.

The highest weed biomass, 2,320 gm/m^2, occurred with CT; in contrast, biomass averaged across the other four treatments was less than 50% of biomass in CT (Table 1). Weed biomass in the CC treatment was higher than the NT, ST, and ST + CC treatments because of the less competitive canopy due to the lower corn population with CC.

The pattern and time of weed seedling emergence differed between CT and the other four treatments (Figure 2). Weed seedlings emerged earlier with CT, with the highest number of seedlings occurring on May 28; in contrast, the highest number of weed seedlings with NT was recorded on June 18. More than 85% of weed seedlings in CT had emerged by June 18. We attribute the later emergence of the weed community with NT to cooler soil temperatures (Carter and Barnett 1987). A similar delay of weed seedling emergence occurred with the CC, ST, and ST + CC treatments compared with CT (data not shown).

Implications for Crop Residue and Weed Management.
Our study indicates that producers in eastern South Dakota have flexibility in managing spring wheat residues for corn production. Corn yield did not differ among NT, CT, and ST treatments in weed-free conditions, even though environmental conditions during the early growing season differed across years. Strip-till was effective for corn production, particularly in weed-infested conditions, but it has some limitations. First, input costs increase with the additional tillage operation, and second, N fertilizer is more prone to leaching in the soil profile, especially with fall applications (Vetsch and Randall 2004).

Strip-till increased corn tolerance to weeds (Figure 1), which we partially attributed to N placement. Scientists are developing more effective fertilizer management tactics that improve corn growth in NT, high-residue conditions, which may also increase corn tolerance to weeds. For example, corn growth was improved by applying a starter fertilizer in the seed furrow compared with fertilizer placed 5 cm to the side of the crop row (Vetsch and Randall 2000) and by including sulfur and K with N and P in the starter fertilizer (Niehaus et al. 2004; Wortman et al. 2006). With these studies, the remainder of the N fertilizer was placed in a band below the crop residue layer on the soil surface. Kravchenko and Thelen (2007) further improved corn yield in NT winter wheat stubble by adjusting N fertilizer rates for the in-crop band application to compensate for N immobilization by crop residue.

Interest in establishing corn in spring wheat stubble with NT is guided by a weed management program developed in the semiarid Great Plains. With NT, crop residue preservation on the soil surface, and rotations comprising crops with different life cycles, producers are managing weeds with 50% less cost compared with the conventional production system (Anderson 2005). Along with a possible benefit for weed management, adding spring wheat to the corn–soybean rotation may improve crop yield. Zhang et al. (1996) noted, in a long-term rotation study in Ontario, Canada, a 46% increase in corn yield in a corn–soybean–wheat rotation compared with a corn–soybean rotation. They attributed increased corn yields to wheat improving soil health across time.

In addition, corn grown with NT and crop residues on the soil surface may yield more during dry years compared with tilled systems. In the semiarid Great Plains, corn yielded between 15 and 50% more in NT systems because of water conservation (Anderson 2004; Wicks et al. 1994). Swan et al. (1994) reported a similar trend in Wisconsin during years of below normal precipitation; corn yielded more with NT, high-residue systems than tilled systems.

Sources of Materials

[1] Residue managers. Dawn Equipment Company, P.O. Box 497, Sycamore, IL 60178.

[2] NK 3030 LL corn. Syngenta Seeds, Inc. P.O. Box 8353, Wilmington, DE 19803.

[3] Statistix. Analytical Software. P.O. Box 12185, Tallahassee, FL 32317.

[4] Sigma Plot. Jandel Scientific, Point Richmond, CA 94804.

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